

Vernadsky and Biospherical Ecology*

by

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1. INTRODUCTION: GLOBAL ECOLOGY, THE BIOSPHERE, AND VERNADSKY

For most people, the rise of global ecology (e.g. Bolin, 1979; Budyko, 1980, 1986; Southwick, 1985) — the ecology of the whole of Earth's Biosphere — dates mainly from the earlier 1970s (Polunin, 1972), as it was at that time of 'environmental revolution' that the realization of our complete dependence on our planetary Biospherical environment started to become at all widespread in enlightened circles. Such realization of the truth has latterly gathered more and more momentum, but never in sufficient volume or fast enough to satisfy its most dedicated adherents or, we fully believe, the best interests of our world.

During the 1980s, the idea that The Biosphere could be seriously, even drastically, disturbed by a nuclear conflict or mere accident, became a new subject of international concern. Interdisciplinary study by ICSU's SCOPE **, and others, of the global environmental consequences of nu-

clear war followed, with much-needed international scientific collaboration. The so-called 'nuclear winter' is a resultant, important argument emphasizing the interconnections of all the parts of The Biosphere. The human demomass thus turned some of its concern from the face of the Earth to the fate of Earth's Biosphere.

But, as we know, The Biosphere — the initial letters of which we capitalize thus to dignify our only known natural habitat in the cosmos — is also threatened with many other major ecological disasters (Polunin, 1980; 1987a, 1987b; Ramade, 1987), such as that of stratospheric ozone depletion (e.g. Dütsch, 1987; Gribbin, 1988; Rowland, 1988), the increasing concentration of carbon dioxide and other 'greenhouse' gases in the atmosphere (with probable effects on global climate, heightened by deforestation and other devegetation) (e.g. Flohn, 1980), the continued destruction of the world's tropical forests with extinction of many plant and animal species at an unprecedented rate and concomitant dramatic losses of genetic diversity (e.g. Prance & Elias, 1977), and yet other looming ecodisasters (Polunin, 1980; Polunin & Burnett, in press).

The Man-made threats to The Biosphere which we share with all living things are very real, though often pitifully little recognized. Yet all nations and peoples are concerned, as we have indeed 'Only One Earth' (Ward & Dubos, 1972). Our planet is a very peculiar one, basically because of its unique and hitherto ever-evolving Biosphere; but many points illustrate the fact that this scientific concept of The Biosphere is not yet familiar, unfortunately, to the vast majority of people†.

In the development of this all-important concept and reality of Earth's Biosphere, the historic figure and work of Vladimir Ivanovich Vernadsky (1863–1945) must take pride of place as the first, far-sighted pioneer. Yet it is a striking and deplorable fact that Western scientific culture,

† This unhappy and potentially dangerous situation may, however, be changing with such newsworthy 'scares' as the aforementioned one to the stratospheric ozone layer (Rowland, 1988) and the announcement since this Kiev Session that the DuPont Company, which is by far the world's largest producer of chlorofluorocarbons, is starting soon to phase out their production. — Ed.

*Paper presented in the Kiev Session, on 'Vernadsky's Theory of Biosphere and Problems of Environmental Protection', of the International Symposium marking the Commemoration of the 125th Birthday Anniversary of Academician V.I. Vernadsky (see pp. 187–9 of this issue), held in the Great Conference Hall, Ukrainian SSR Academy of Sciences, on 9 March 1988, under the Chairmanship of its Vice-President, Academician K.M. Sitnik. Given by the first-named Author, who opened with the explanation: 'In the first place I must explain that the title of this paper, to be presented under six headings, is not at all as printed in the programme, but follows the theme which I *thought* was agreed to when the organizers of this impressive Commemoration telephoned me from Moscow. Also, most importantly, this paper is by a collaborator in the University of Geneva, Switzerland, whence we come, Dr Jacques Grinevald, and myself, our title being as given above.'

We now understand that this, slightly reworked, version of our paper will be published in Russian by the USSR Academy of Sciences but that this publication of the English version following due refereeing will be welcomed by our hosts on that memorable occasion.

** ICSU being the acronym standing for the International Council of Scientific Unions — in several senses the world's top scientific body — SCOPE is the acronym for its Scientific Committee on Problems of the Environment. — Ed.

of which the English language is now by far the most-used vehicle, until recently disregarded Vernadsky's work and much that is symbolized by it. This included the holistic concept of The Biosphere, the study of the biogeochemical cycles of The Biosphere and their alteration by human activities, and integrating studies of the Earth as a whole. Now, however, matters are changing, especially with such activities as the IIASA Biosphere Project, the ICSU International Geosphere-Biosphere Programme, and the NASA Earth System Science (Malone & Roederer, 1985; Clark & Munn, 1986; Malone, 1986; NASA Advisory Council, 1988).

Even the proposers of the 'Gaia hypothesis' of the Earth being a living entity controlled by life, now admit that they were unaware of Vernadsky's work until the 1980s. Thus in a review of the recent English translation of Vernadsky's *The Biosphere*, the English atmospheric chemist James E. Lovelock declared: 'When Lynn Margulis and I introduced the Gaia hypothesis in 1972, neither of us was aware of Vernadsky's work and none of our much-learned colleagues drew our attention to the lapse. We retraced his steps and it was not until the 1980s that we discovered him [Vernadsky] to be our most illustrious predecessor' (Lovelock, 1986).

2. CONCEPTUAL AND TERMINOLOGICAL CONFUSION

An early point to clarify is the plurality of different meanings that have been associated with the term *biosphere* in scientific literature. For us *The Biosphere* is the '... integrated living and life-supporting system comprising the peripheral envelope of Planet Earth together with its surrounding atmosphere so far down, and up, as any form of life exists naturally.* This concept, stemming from Vernadsky, was already recalled by G. Evelyn Hutchinson (1970) in his authoritative paper introducing the special issue of *Scientific American* devoted to 'The Biosphere', by the celebrated Soviet soil scientist Victor Abrahamovich Kovda (1970) in the first chapter (entitled 'Contemporary scientific concepts relating to the biosphere') of the proceedings of the UNESCO so-called 'Biosphere Conference', and by one of us in the first International Conference on Environmental Future, held in Finland in 1971 (Pulvin, 1972).

The term *Biosphere* was coined by the Austrian geologist Eduard Suess [1831–1914] in the last and most general chapter of his slim 1875 book on the genesis of mountains, entitled *Die Entstehung der Alpen*, though unfortunately in that and his subsequent multi-volume *Das Antlitz der Erde*, the last volume of which was published as late as 1909, he never really defined his term. Nevertheless with Pierre Teilhard de Chardin [1881–1955], then professor of geology at the Institut Catholique in Paris, Vernadsky was an enthusiastic user of the term in developing his concept of The Biosphere, as will be clear from a forthcoming book by one of us (Grinevald, in prep.).

* See also page 177 of this issue, whereon is recorded the enthusiastic approval of this definition by 'an audience of some 320 (apart from the platform party)' including foreign participants of the Vernadsky Commemoration described on pp. 187–9 of this issue. — Ed.

Most unfortunately, mistaking its true biological basis, Chardin used the term invented by Suess in an entirely different sense from that of Vernadsky, explaining in a footnote his definition of 'the Biosphere' as 'This term, invented by Suess, is sometimes interpreted (Vernadsky) in the sense of the "terrestrial zone containing life". I use it here to mean the actual layer of vitalized substance enveloping the earth.' (Chardin, 1977 p. 163). Much the same idea of such a 'biosphere' being the totality of living matter of all organisms was often attributed to Jean-Baptiste Lamarck, which may in part explain why Western commentators on Chardin's work have ignored Vernadsky. The question of The Biosphere and the Noosphere (sphere of influence of Mankind) is currently being re-examined by one of us (Grinevald, 1987a, 1987b, in press, MS, in prep.).

After Suess, the term 'biosphere' was widely used to designate only the 'organic world' in the sense of the totality of all living organisms — a sense that still prevails in some manuals and even learned quarters today, which, for example, refer to the lithosphere, the hydrosphere, the atmosphere, and the biosphere. Less harmfully confusing — provided the basis is made clear — is the view that The Biosphere (understood in Vernadsky's and our sense) should involve all matters, and include all spaces, which have been affected in any way by life, even if none is still present — hence being the sphere of *influence* of life (past and/or present).

In flagrant disregard of Vernadsky's teachings, the American ecologist Lamont C. Cole (1958) introduced the neologism *ecosphere*, which has sometimes been adopted since (e.g. Gillard, 1969), while the results of the International Biological Programme [1964–74] were presented as the quantitative study of the 'primary productivity of the biosphere'. In a book having this title, Helmut Lieth & Robert H. Whittaker (1975) remarked: 'This volume refers to 'biosphere' in the first sense ('the global film of organisms') ...' — which merely adds to the confusion! We accordingly feel it to be important to stabilize use of our key term in Vernadsky's fully scientific sense, and consider it a duty to propose a resolution to that effect.*

3. VERNADSKY AND THE HISTORY OF ECOLOGY

Although neglected by many historians of ecology and of science in general, *Biosfera (The Biosphere)*, published by Vernadsky in 1926 in Russia, in 1929 in France (Vernadsky, 1929; cf. Grinevald, 1986), and in 1930 in Germany, is, we believe, a major landmark in our intellectual history and global understanding. In it Vernadsky adopted a new scope of perception, viewing The Earth as a 'living planet' in the solar system, and presenting the concept of The Biosphere as a 'scientific revolution'.

Now we are wondering whether, in the manner of the 'Wegenerian revolution' proposed in 1968 by the Canadian geophysicist 'Jock' Tuzo Wilson (Wilson, 1968a, 1968b), we should not think very seriously about a 'Vernadskyan revolution' to embrace his vast concept, which could effec-

* Subsequently done and carried by acclamation as the first of the 'Vernadsky Commemoration "Round Table Resolutions"', as described on p. 177 of this issue. — Ed.

tively lead to major advances in environmental education and ultimately in world well-being. At least such a Biospherical revolution of thought should constitute an important, special facet of the environmental movement, as we suggested in Leningrad†. Our Earth is mobile, dynamic and 'living'; we must understand our global environment as a whole — to improve our capacity to detect and respond to warnings of any major change. This is a new challenge for the international scientific community.

The fact that Vernadsky was the first natural scientist, in the 1920s, to define The Biosphere within a very modern thermodynamic and biogeochemical perspective, despite some mistakes due to the state of science at the time, merits our respectful gratitude, and should be widely acknowledged. In the manner of at least one other vital concept which we are not at present at liberty to divulge, the basic theme was too simple to have attracted attention until Vernadsky advanced it, and even then it was very slow in taking root at all widely.

The links between Vernadsky and modern ecological thought are now at last well inscribed in the history of ecology. His work also had links with other fields, including economics (Vernadsky, 1924, 1925; Grinevald, 1987b; Martinez-Alier, 1987). Nor is it our task to speak about the influence of Vernadsky on Russian ecology and the environmental movement in the Soviet Union. We recall here only the relationship between Vernadsky's biogeochemical concept of The Biosphere and the concept of the 'biogeo-coenose' developed by the Russian plant ecologist Vladimir Nikolaevich Sukachev and his school of thought (Sukachev & Dylis, 1968; Fortescue, 1980).

In the English-speaking countries, G. Evelyn Hutchinson provided the missing link between Vernadsky's work and ecology. At Yale he was a close colleague of the Russian naturalist Alexander Petrunkevich (a former pupil of Vernadsky) and a friend of the late George Vernadsky, the scientist's historian son. Another supporter of this theme was Raymond L. Lindeman [1916–42], author of the notable article entitled 'The trophic-dynamic aspect of ecology' (1942), who was also an associate of Hutchinson at Yale. In this contribution to ecosystem ecology, written seven years after the British plant ecologist Sir Arthur G. Tansley [1871–1955] had coined the term *ecosystem* (1935) for his new concept, Lindeman explained his trophic-dynamic viewpoint, emphasizing the energy-flow and nutrients' cycling within a whole ecosystem as being closely allied to Vernadsky's biogeochemical approach already adopted by Hutchinson; and Vernadsky's *La Biosphère* was included in the literature which Lindeman cited.

In an autobiographical book, G. Evelyn Hutchinson wrote, 'I did my best to help Petrunkevich and George Vernadsky [to] make his [V.I. Vernadsky's] ideas about the

biosphere better known in English-speaking countries' (Hutchinson, 1979 p. 233).

A man of unusual foresight, Hutchinson was also instrumental in the publication in America of two of Vernadsky's works, George Vernadsky being the translator. The first work was under the editorship of Hutchinson himself and was published in 1944 in the *Transactions of the Connecticut Academy of Arts and Sciences* (Vernadsky, 1944); the second, more diffuse, entitled 'The Biosphere and the Noosphere', was published in *American Scientist* in January 1945 with the following footnote: 'The sad news of Academician Vernadsky's death on January 6, 1945, has reached us in going to press.' In a foreword the Editor (Hutchinson?) wrote this laudatory tribute: 'The two contributions together present the general intellectual outlook of one of the most remarkable scientific leaders of the present century' (Vernadsky, 1945a). In addition, Hutchinson published several studies of biogeochemistry, which he treated as a new science (Vernadsky, 1945b) created by Vernadsky (Hutchinson, 1943), while at the 1948 AAAS symposium on 'The World's Natural Resources', he provided a wide intellectual framework for an 'anthropogeochemistry of cultural life' under the significant title 'On Living In The Biosphere' (Hutchinson, 1948).

4. IMPORTANCE OF THE CONCEPT OF BIOSPHERE

There can be no question of the vital and vast significance of the concept of Biosphere in our modern world, even as its actuality provides almost all the components of the life-support of Man and Nature. Yet, looking back historically, it seems extraordinary indeed that nobody appears to have had, or anyway developed and published, these ideas until they were so clearly enunciated by Vladimir Ivanovich Vernadsky less than 70 years ago. And now The Biosphere is emerging as a vital overall reality that we need to maintain intact and cherish perhaps even more ardently than any particular part or factor of our planet's terrestrial or aquatic surface.

To be sure, the approximate limits (Vernadsky, 1929) to which life extends naturally up in the atmosphere as spores and yeasts etc. (e.g. Polunin *et al.*, 1947; Polunin, 1951) and down in the lithosphere as chemosynthetic Bacteria (e.g. Winogradsky, 1949; Margulis & Sagan, 1987), have only become known relatively recently, and, from their very nature, must remain imprecise. So must the dependent limits of our Biosphere, though it has long been known that they include the deepest depths of the oceans and ocean troughs. There has also been the unfortunate confusion of other interpretations to which we have already referred. But such questions are largely academic, and do not detract from the vast importance of the concept of the great thinker.

Suffice it to say here that, after The Universe, The Biosphere is in several respects probably the greatest reality with which we, as humans, have to deal; and yet we are threatening it in many ways, of which most stem basically from our increasingly too-great numbers and profligacy. We should also beware that, from some of the changes wrought by humans, the dangers lie in their subtlety, so that they are liable to be overlooked until the period is too late for remedy, whereas others appear drastically, even sud-

† and subsequently got approved in resolution form in Moscow — see the Vernadsky Commemoration 'Round Table Resolutions', described on p. 117 of this issue. The wording of this second resolution, which was also passed by a large mixed audience by acclamation, was 'The environmental movement being now well-established globally, it is resolved henceforth to recognize what may be termed the 'Vernadskyan revolution' as an important aspect of it, calling on all involved bodies and interests to pay special attention to [that revolution's] main thrust of the healthful maintenance of The Biosphere.'

denly, after reaching a threshold or being triggered unexpectedly.

5. NECESSITY OF SAFEGUARDING THE BIOSPHERE

In view of what we have just been digesting, it is clearly one of the greatest imperatives of our time, and indeed of all time, to safeguard The Biosphere and maintain its integrity in every possible way. Concerning this we recently held a conference entitled 'Maintenance of The Biosphere' (Polunin, 1987*b*; Polunin & Burnett, in prep.), which was followed by a tour around the world talking about our choice of 20 ways in which it seems 'Our World [is] Menaced' and, with it, The Biosphere (Polunin, 1987*c*).

Fortunately there are, nowadays, increasing numbers of enlightened people and even governments who understand the situation and realize its potentially extreme gravity. This, albeit belated, realization has been helped by the information 'media' making much of nuclear possibilities and, latterly, of various threats to the stratospheric ozone shield, to the world's climates through the so-called 'greenhouse effect', and to what remain of the world's great forests.

Fortunately, too, much is now starting to be done to counter these and others of the more obvious threats to The Biosphere's integrity — we can only hope in time, and press for it to be prosecuted with sufficient dedication and speed. But then there are the less obvious dangers, such as increasing desertification, and doubtless others that have yet to emerge. For instance who, only a few years ago, would have thought that the stratospheric ozone shield could be seriously threatened with depletion; and yet it is one of the conditions without which life could scarcely have developed on Earth, at least as we know it, and without which its equitable maintenance would be problematical at best. Yet human overpopulation remains the greatest basic threat.

6. TOWARDS RECOGNITION OF THE BIOSPHERE AND HER PROBLEMS

Nearly a decade ago there came to us, from Canada, Dr John R. Vallentyne with the idea of an International Year of The Biosphere, which in time developed into The World Campaign for The Biosphere (Anon., 1982; Pauling *et al.*, 1982; Polunin, 1982, 1984). In its quiet way this has been, and continues to be, quite widely supported — not least by issuance of special 'Save Our Biosphere' stickers and sports-shirts from India, and by various publications and demonstrations there and elsewhere. Meanwhile, as 'Johnny Biosphere', Vallentyne continues to speak before enthusiastic audiences practically world-wide — commonly with a symbolic globe on his back (Vallentyne, 1984), whence emanate telling 'Biospherical' noises. He now reckons that he must have been seen in the flesh or on television, or anyway heard on the radio, by a considerable proportion of the people now living on Earth, and meanwhile has developed a 'Behavioural Code of Practice for Living in The Biosphere' (Vallentyne, 1986).

Another thrust which an international group of us founded some years ago is the World Council For The Biosphere (WCB), which has recently been expanded with the adoption of its own Constitution though remaining under the general aegis of the Foundation for Environmen-

tal Conservation. Its main objectives are to (A) alert decision-makers to potential threats to the integrity of The Biosphere especially from human activity, and, whenever and wherever possible, recommend measures to counter those threats; (B) advise on ways to improve the sustainability of desirable economic systems while maintaining the integrity of the ecological systems that form the main bases of continuing human activity and productivity; (C) foster ecologically sensitive thinking and action, bearing in mind the holistic nature of The Biosphere, in which each and every part should contribute to its overall functioning; (D) investigate the limits and validity of key assumptions underlying predictions especially regarding the integrity of The Biosphere; (E) warn against specific dangers to The Biosphere, including major pollutions, breakdown or malfunctioning of Man-made devices, and misguided practices; (F) promote the World Campaign for The Biosphere as a global, primarily educational effort to increase public awareness and understanding of The Biosphere and our utter dependence on it, and (G) advise the International Society For Environmental Education (ISEE) and its national and other affiliates on leading concepts and critical issues to be considered in their development of educational materials and programmes for decision-makers, the young, and the general citizenry, throughout the world.

To conclude we'll merely mention one more item to come, provided only that we can find the necessary finance — a Fourth (and for its organizer final, at least as regards primary responsibility) International Conference on Environmental Future, this time on the theme of Threats to The Biosphere and Imperative Countermeasures. Such a conference should form a useful part of the above-suggested Biospherical revolution of thought inspired by Vernadsky. May we add one simple belief: what we should really look to — worship if you will — is not some hypothetical deity but life itself. As suggested on page 177 of this issue, such an objective could give to the [International] Vernadsky Foundation a highly positive thrust.*

SUMMARY

The concept of The Biosphere as the integrated living and life-supporting system comprising the peripheral envelope of planet Earth together with its surrounding atmosphere so far down, and up, as any form of life exists naturally, stems from the writings of V.I. Vernadsky in the 1920s but has only emerged and become widely accepted in the latest decades. Yet it is quite one of the largest and most important entities with which humans have to deal, being, moreover, the only natural habitat and life-support of Mankind and Nature and, as such, needful of safeguarding and healthful maintenance.

No other meaning than the above should be attached to the term Biosphere, the importance of which concept and actuality being such that it should be far more widely known than is currently the case — to which end a small conference was held in 1987 and a larger one is contemplated in 1990 on the theme of Threats to The Biosphere and Imperative Countermeasures.

* This Foundation was established on the final day of the Vernadsky Commemoration as indicated elsewhere in this issue (Polunin, 1988*a*, 1988*b*).

Other activities on behalf of The Biosphere include the 'Johnny Biosphere' media campaign of Dr John R. Vallen-tyne, those of The World Campaign for The Biosphere and its sponsoring World Council For The Biosphere, and the newly-established [International] Vernadsky Foundation which it is hoped will have, as one of its main objectives, the fostering of due reverence for life in its full Biospherical context.

REFERENCES

- ANON. (1982). Declaration: The World Campaign for The Biosphere. *Environmental Conservation*, **9**(2), pp. 91–2.
- BOLIN, B. (1979). Global ecology and Man. Pp. 27–56 in *Proceedings of the World Climate Conference, Geneva, Switzerland, 12–23 February 1979*. (WMO No. 537.) World Meteorological Organization, Geneva, Switzerland: xii + 791 pp.
- BUDYKO, M.I. (1980). *Global Ecology*, transl. from the Russian. Progress Publishers, Moscow, USSR: 323 pp.
- BUDYKO, M.I. (1986). *The Evolution of the Biosphere*, transl. from the Russian. Reidel, Dordrecht, Netherlands: xv + 423 pp.
- CHARDIN, P. Teilhard de (1977). *The Future of Man*, transl. from the French. (Fount Paperbacks.) Collins, London, England, UK: 332 pp.
- CLARK, W.C. & MUNN, R.E. (Eds) (1986). *Sustainable Development of the Biosphere*. International Institute for Applied Systems Analysis, Laxenburg, Austria, and Cambridge University Press, Cambridge, England, UK: viii + 491 pp., illustr.
- COLE, Lamont C. (1958). The ecosphere. *Scientific American*, **194**(4), pp. 83–96.
- DÜTSCH, H.U. (1987). Guest Comment: The Antarctic 'Ozone Hole' and its possible global consequences. *Environmental Conservation*, **14**(2), pp. 94–7, 2 figs.
- FLOHN, H. (1980). Man's increasing impact on Earth's climate: Atmospheric Processes. Pp. 31–44 (and following Discussion to p. 59) in Polunin (1980), *q.v.*
- FORTESCUE, J.A.C. (1980). *Environmental Geochemistry: A Holistic Approach*. (Ecological Studies 35.) Springer-Verlag, New York-Heidelberg-Berlin: xvii + 347 pp.
- GILLARD, A. (1969). On terminology of biosphere and ecosphere. *Nature* (London), **223**, pp. 500–1.
- GRIBBIN, J. (1988). *The Hole in the Sky: Man's Threat to the Ozone Layer*. Corgi Books, London, England, UK: xiv + 192 pp.
- GRINEVALD, J. (1986). [Review of] 'The Biosphere' by Vladimir I. Vernadsky. *Environmental Conservation*, **13**(3), pp. 285–6.
- GRINEVALD, J. (1987a). Le développement de/dans la biosphère. Pp. 29–44 in *L'homme inachevé*, Cahiers de l'I.U.E.D. 17, Genève, Switzerland, and Presses Universitaires de France, Paris, France: 169 pp.
- GRINEVALD, J. (1987b). *Vernadsky and Lotka as Source for Georgescu-Roegen's Bioeconomics*. Paper presented at the International Conference on Economics and Ecology, Universitat Autònoma de Barcelona, Barcelona, Spain, 26–29 September 1987: 23 pp. (mimeogr.).
- GRINEVALD, J. (in press). On a holistic concept for deep and global ecology: The Biosphere. *Fundamenta Scientiae*, **8**(2).
- GRINEVALD, J. (MS.). Sketch for a history of the idea of The Biosphere. In *Proceedings of the Gaia Conference 1987*, Eds Peter BUNYARD & Edward GOLDSMITH.
- GRINEVALD, J. (in prep.). *La Biosphère de la Planète Terre: Origines, Evolution et Actualité d'Un Concept Holistique*. (Rapport à ECOROPA.) Sang de la Terre, Paris, France.
- HUTCHINSON, G.E. (1943). The biogeochemistry of aluminium and certain related elements. *Quarterly Review of Biology*, **18**(1), pp. 12–29.
- HUTCHINSON, G.E. (1948). On Living In The Biosphere. *Scientific Monthly*, **67**, pp. 383–98.
- HUTCHINSON, G.E. (1970). The Biosphere. *Scientific American*, **223**(3), pp. 45–53. (Special number devoted to *The Biosphere*, reissued as 'A Scientific American Book'. Freeman, San Francisco, California, USA: vii + 134 pp., 1970.)
- HUTCHINSON, G.E. (1979). *The Kindly Fruits of the Earth: Recollections of an Embryo Ecologist*. Yale University Press, New Haven, Connecticut, USA: xxx + 264 pp.
- KOVDA, V.A. (1970). Contemporary scientific concepts relating to the biosphere. Pp. 13–29 in *Use and Conservation of the Biosphere: Proceedings of the Intergovernmental Conference of Experts on the Scientific Basis for Rational Use and Conservation of the Resources of the Biosphere*. ('Natural Resources Research X'.) UNESCO, Paris, France: 272 pp.
- LIETH, H. & WHITTAKER, R.H. (1975). *Primary Productivity of the Biosphere*. (Ecological Studies 14.) Springer-Verlag, Berlin-Heidelberg-New York: vi + 339 pp.
- LINDEMAN, R.L. (1942). The trophic-dynamic aspect of ecology. *Ecology*, **23**, pp. 399–418, illustr.
- LOVELOCK, J.E. (1986). Prehistory of Gaia. *New Scientist*, **111** (1517), p. 51.
- MALONE, T.F. (1986). Mission to Planet Earth: integrating studies of global change. *Environment*, **28**(8), pp. 6–11 & 39–42.
- MALONE, T.F. & ROEDERER, J.G. (Eds) (1985). *Global Change: The Proceedings of a Symposium Sponsored by the International Council of Scientific Unions (ICSU) during its 20th General Assembly in Ottawa, Canada, on September 25, 1984*. ICSU Press & Cambridge University Press, Cambridge, England, UK: xxviii + 512 pp.
- MARGULIS, L. & SAGAN, D. (1987). *Microcosmos: Four Billion Years of Microbial Evolution*. Allen & Unwin, London, England, UK: 301 pp.
- MARTINEZ-ALIER, J. (1987). *Ecological Economics*. Basil Blackwell, Oxford, England, UK: ix + 286 pp.
- NASA Advisory Council (1988). *Earth System Science: A Closer View*. National Aeronautics and Space Administration, Washington, DC, USA: 208 pp.
- PAULING, Linus, BENAVIDES, Felipe, WAHLEN, Friedrich T., KASSAS, Mohamed & VOHRA, B.B. (1982). Open Letter: To all who should be concerned. *Environmental Conservation*, **9**(2), pp. 89–90.
- POLUNIN, Nicholas (1951). Seeking botanical particles about the North Poles. *Svensk Botanisk Tidskrift*, **45**(2), pp. 320–54, illustr.
- POLUNIN, Nicholas (1972). The Biosphere today. Pp. 33–52 (and Discussion and Addenda to page 64) in *The Environmental Future: Proceedings of the first International Conference on Environmental Future, held in Finland from 27 June to 3 July 1971*, Ed. N. Polunin. Macmillan, London, England, UK, and Barnes & Noble, New York, NY, USA: xiv + 660 pp., illustr.
- POLUNIN, Nicholas (Ed.) (1980). *Growth Without Ecodisasters? Proceedings of the Second International Conference on Environmental Future, held in Reykjavik, Iceland, 5–11 June 1977*. Macmillan, London & Basingstoke, England, UK, and Halsted Press Division of John Wiley & Sons, New York, NY, USA: xxvi + 675 pp., illustr.
- POLUNIN, Nicholas (1982). Our global environment and the World Campaign for The Biosphere. *Environmental Conservation*, **9**(2), pp. 115–21, 2 figs.
- POLUNIN, Nicholas (1984). Geneses and progress of the World Campaign and Council For The Biosphere. *Environmental Conservation*, **11**(4), pp. 293–8, 2 figs.
- POLUNIN, Nicholas (1987a). Editorial: Our world menaced. *Environmental Conservation*, **14**(2), pp. 99–100.
- POLUNIN, Nicholas (1987b). Third International Conference on Environmental Future: Maintenance of The Biosphere, held in the University of Edinburgh, Scotland, UK, during 24–26 September 1987. *Environmental Conservation*, **14**(4), pp. 372–3, 2 figs.
- POLUNIN, Nicholas (1987c). [Notes for] *Around the World Talk ... Our World Menaced*. The Foundation for Environmental Conservation, Geneva, Switzerland: 7 pp. (mimeogr.)
- POLUNIN, Nicholas [as N.P.] (1988a). Vernadsky Commemoration 'Round Table' Resolutions. *Environmental Conservation*, **15**(2), p. 177.
- POLUNIN, Nicholas (1988b). Jubilee events dedicated to Academician V.I. Vernadsky's 125th Birthday anniversary, including

- International Symposium held in Leningrad, Kiev, and Moscow, during 4–12 March 1988. *Environmental Conservation*, **15**(2), pp. 187–9.
- POLUNIN, Nicholas & BURNETT, Sir John (Eds) (in prep.). *Maintenance of The Biosphere: Proceeding of the Third International Conference on Environmental Future, held in Edinburgh, Scotland, 24–26 September 1987*. Edinburgh University Press, Edinburgh, Scotland, UK.
- POLUNIN, Nicholas, PADY, S.M. & KELLY, C.D. (1947). Arctic aerobiology. *Nature* (London), **160**, pp. 876–7.
- PRANCE, G.T. & ELIAS, T.S. (Eds) (1977). *Extinction is Forever: The Status of Threatened and Endangered Plants of the Americas*. New York Botanical Garden, Bronx Park, New York, N.Y., USA: vi + 437 pp., illustr.
- RAMADE, F. (1987). *Les Catastrophes écologiques*. McGraw-Hill, Paris, France: v + 318 pp.
- ROWLAND, F.S. (1988). Chlorofluorocarbons, stratospheric ozone, and the Antarctic 'ozone hole'. *Environmental Conservation*, **15**(2), pp. 101–15, 5 figs.
- SOUTHWICK, C.H. (1985). *Global Ecology*. Sinauer Associates Inc., Sunderland, Massachusetts, USA: xi + 323 pp.
- SUKACHEV, V.N. & DYLLIS, N. (1968). *Fundamentals of Forest Biogeocoenology*, transl. from the Russian (1964). Oliver & Boyd, Edinburgh & London, UK: viii + 672 pp.
- TANSLEY, Arthur G. (1935). The use and abuse of vegetational concepts and terms. *Ecology*, **16**, pp. 284–307.
- TEILHARD DE CHARDIN, P. – see CHARDIN, P. Teilhard de
- VALLENTYNE, John R. (1984). 'Johnny Biosphere'. *Environmental Conservation*, **11**(4), pp. 363–4, 2 figs.
- VALLENTYNE, John R. (1986). The necessity of a behavioural code of practice for living in The Biosphere. Pp. 406–14 in *Ecosystem Theory and Application* (Ed. Nicholas POLUNIN). John Wiley & Sons, Chichester–New York–Brisbane–Toronto–Singapore: xv + 445 pp., illustr.
- VERNADSKY, V.I. (1924). *La Géochimie*. Félix Alcan, Paris, France: iv + 404 pp.
- VERNADSKY, V.I. (1925). L'autotrophie de l'humanité. *Revue Générale des Sciences*, **36**, pp. 495–502.
- VERNADSKY, V.I. (1929). *La Biosphère*. (Nouvelle collection scientifique.) Félix Alcan, Paris, France: xii + 232 pp.
- VERNADSKY, V.I. (1944). Problems of Biogeochemistry. II: The fundamental matter–energy difference between the living and the inert natural bodies of the biosphere (Transl. by G. VERNADSKY, edited and condensed by G.E. HUTCHINSON.) *Transactions of the Connecticut Academy of Arts and Sciences*, **35**, pp. 483–517.
- VERNADSKY, V.I. (1945a). The Biosphere and Noosphere. *American Scientist*, **33**, pp. 1–12.
- VERNADSKY, V.I. (1945b). La biogéochimie. *Scientia*, **77–8**, pp. 77–84.
- VINOGRADSKI, Sergei Nikolaevich — see WINOGRADSKY, S.
- WARD, Barbara & DUBOS, René (1972). *Only One Earth: The Care and Maintenance of a Small Planet*. Norton, New York, NY, USA: xxv + 225 pp., illustr.
- WILSON, J.T. (1968a). The current revolution in earth sciences. *Transactions of the Royal Society of Canada*, **6**, pp. 273–81.
- WILSON, J.T. (1968b). Static or mobile earth: the current scientific revolution. *Proceedings of the American Philosophical Society*, **112**(5), pp. 309–20.
- WINOGRADSKY, S. [Sergei Nikolaevich Vinogradski] (1949). *Microbiologie du Sol*. Masson, Paris, France: 861 pp.